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Results and Final Report from the Applied Research Proposal for the Explosive Destruction of Chemical Munitions

Dstl/CR01801

J M Waters

28th September 2001

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UK

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Abstract

Product Manager for Non-Stockpile Chemical Material (PMNSCM) at Edgewood Chemical and Biological Centre proposed techniques whereby recovered chemical weapons are destroyed by explosive opening and chemical neutralisation within a closed system. A prototype was designed to test the practicality of this proposed solution and preliminary proofing work was conducted in the US. Previous toxic trials conducted by the Defence Science and Technology Laboratory (Dstl) at Porton Down, UK proved provisional proof of principle for the destruction of munitions containing phosgene and mustard, but subsequent improvements were necessary in the prototype and more data was required to fully demonstrate proof of principle. This proposal covers the provision, by Dstl of facilities and skilled personnel to enable PMNSCM to assess and develop the techniques by challenge with live CW agents and aged CW munitions.

This document describes the results of the trials described in the Applied Research Proposal for the Explosive Destruction of Chemical Munitions System and the Addition to Applied Research Proposal for the Explosive Destruction of Chemical Munitions (US Army Contract No. N68171-01-C-9014).

Contents

1. Background

1.1 Introduction

1.1.1 Non-stockpile chemical munitions are a continuing problem and pose a hazard to both service personnel and the public. In addition, the aged state of many munitions poses extra problems in terms of leakage and transport. These many problems have been recognised by Product Manager for Non-Stockpile Chemical Material (PMNSCM) and a need was identified to develop the capability for destroying old and abandoned ("non-stockpile") chemical munitions.

1.1.2 Dstl was pleased to collaborate with PMNSCM in order to advance the understanding of the chemical materials and processes necessary for the controlled transformation of these toxic materials to relatively benign products in transportable chemical reactors. An Applied Research Proposal was, therefore, submitted to the US Army Eurpoean Research Office in direct response to the Broad Agency Announcement of June 1999. The proposal falls into the category of Applied Research in Research Area 1 (Chemistry) of the Army Research Office.

1.1.3 Dstl CBS Porton Down, and the Demilitarisation Group in particular, are pioneers in the development of various approaches to decontamination. A main aim of the group is to actively work along with collaborators in order to develop tailored solutions which address specific CW decontamination problems.

1.2 Background of the Research

1.2.1 PMNSCM at Edgewood Chemical and Biological Centre have proposed techniques whereby recovered chemical weapons can be destroyed by explosive opening and chemical neutralisation within a closed system. A prototype was designed to test the practicality of this proposed solution and preliminary proofing work was conducted in the US. Subsequently the feasibility of the solution was evaluated under the Main Trials Programme at CBS Porton Down (Contract Ref. No. N68171-99-C-9026). This led to further developments in the prototype, which were again evaluated at CBS Porton Down (Contract Ref. No. N68171-00C-9021). Although this trials period provided provisional proof of principle for the destruction of munitions containing phosgene and mustard, improvements were necessary in the prototype and more data was now required to fully demonstrate proof of principle.

1.2.2 CBS Porton Down provides the facilities and skilled personnel to enable PMNSCM to assess and develop the techniques by challenge with live CW agents and aged CW munitions.

1.2.3 This current research concerns assessment of the techniques for use against munitions containing mustard, phosgene or nerve agent (Sarin).

1.3 Defence Science Technology Laboratory (Dstl)

1.3.1 The Defence Evaluation and Research Agency (DERA) was formed in April 1995 to incorporate all the UK Ministry of Defence (MOD) major non-nuclear research organisations. CBD Porton Down is part of DERA and is the UK MOD research centre for chemical defence and destruction of chemical agents. DERA was subsequently split, forming QinetiQ (a Public Private Partnership) with the more sensitive, important parts being retained by MOD and called the Defence Science and Technology Laboratory.

1.3.2 CBS Porton Down has an outstanding international reputation and vast experience of working closely with governments and international consortia on demilitarisation and remediation projects around the world. CBS Porton Down possesses first class facilities and a unique breadth of knowledge across the entire life cycle of munitions and is a world leader in the recovery and disposal of all types of chemical warfare agents. Over 500 scientists and technical specialists, along with support staff, provide a comprehensive, flexible and continually developing range of services on a single site. Services include;

- Indoor test facilities and 7000 acres available for open air field trials
- Specialist field staff with vast experience of safely conducting trails involving super toxic materials
- Munition processing and disposal
- Chemical agent detection and analysis

- Special hazardous waste incineration
- Hazard assessment, modelling and risk management

1.4 The Explosive Destruction System (EDS) Prototype

1.4.1 The EDS consists of a stainless steel pressure vessel approximately 10cm thick with an internal volume of around 200 litres, with a hinged door sealed with a metal-to-metal seal, rubber O-ring and Graylok clamp. The vessel is mounted on a trailer that provides working space, control panels, chemical supply tanks, pumps and other ancillary equipment.

1.4.2 The target munition, fill nominally identified with Portable Isotopic Neutron Spectroscopy (PINS) and explosive configuration checked by X-ray, is mounted in a one-use disposable supporting frame (fragmentation suppression system, FSS) of approximately 1.5cm thick mild steel, with copper Linear Shaped Charge (LSC) mounted around the shell body. Two conical shaped charges are mounted on top of the support aligned with the munition's burster. The munition is opened by detonating the LSC and conical charges using high-voltage detonators supplied from a firing pack via four electrical feedthroughs in the door. The EDS vessel is rated for up to 454 grams (one pound) total of TNT equivalent explosive charge, which is sufficient to allow the explosive opening of munitions up to 4.5" calibre in shell configuration, or a Livens mortar.

1.4.3 Once the munition is opened, neutralising chemical appropriate to the nominal fill is pumped from heated supply tanks on the EDS trailer into the vessel through high-pressure autoclave valves in the door. The vessel can also be heated if necessary, and is oscillated for the reaction time specified in the Standard Operating Procedures (SOPs) by a hydraulic ram mounted beneath the vessel. Samples are taken via sampling ports on the door manifold to confirm the munition's fill and that destruction of agent is complete. The vessel is then emptied to waste drums, and the liquid and solid waste move to a commercial hazardous waste handling facility. Any explosive or chemical agent residue remaining is treated according to local handling procedures.

1.5 Trials Site

1.5.1 The EDS trailer and firing system were located in an enclosed metal-framed building on the Trials Range at Dstl Porton Down. A small lean-to provided space for the monitoring equipment required (eight MINICAMS and a GCMS). There was a limited amount of local mains power (240V 50Hz), and a 200kVA generator to supply the power for the EDS system at 208V 60Hz. Water was provided by bowser. Two canvas tents provided

shelter for emergency decontamination stations, and there were three Portacabins to house the EDS control room and administrative personnel. The Porton Range has controlled access and trials activity is co-ordinated and controlled from a central Range Office with whom the EDS site is in communication by radio or mobile phone. In addition, there was a local communications setup with six portable radios worn by members of the trials team, with a speaker/microphone combination in the control cabin. CCTV coverage of the EDS trailer and the building was relayed from four cameras to TVs and video recorders also within the control cabin.

2. Final Report on the Work Programme

2.1 Introduction

2.1.1 For purposes of reporting the work was divided into six main phases, namely PINs reassessment, maintenance and modification, Training and walkthrough testing of new Standard Operating Procedures (SOPs), Munition Disposal Programme, Clean-up and waste disposal, and technology transfer. These are further detailed below along with other aspects of the work programme.

2.1.2 All US Government equipment used during the trials was been shipped to CBS Porton Down and was returned to the US under already existing contracts (Contract Ref. Numbers N68171-99-C-9026 and N68171-00C-9021).

2.2 PINs Assessment.

2.2.1 Selected munitions were assayed using PINS technology to obtain a high level of confidence in the identification of the chemical fills. Dstl supplied scientific and support staff to operate the PINS facility at Porton Down for the assay. The US Project Manager selected the munitions to be assayed. The PINS technical leader liased with the US experts in the assessment of the PINS data obtained. This increased the level of confidence in the nominal munition fill, and allowed the US EDS project manager to take a more informed decision over which munitions to destroy in the munition disposal test period.

2.3 Maintenance and Modification.

2.3.1 A short maintenance period was conducted before toxic trials and the munition destruction programme began. During this period Dstl staff provided support to personnel from Sandia National Laboratories.

2.4 Training and Walkthrough Testing in new SOPs.

2.4.1 As a result of pervious trials, the US project manager modified several of the SOPs to optimise the destruction of chemical munitions. A period was allowed, therefore, so staff

could familiarise themselves with any new procedures. This was essential in order to meet safety criteria for the subsequent toxic operations.

2.5 Munition Distruction Programme.

2.5.1 After a period of system maintenance and crew refresher training, the munition destruction programme started with a continuation of the mustard munition distruction programme. Munitions enclosed in polythene and those that have been treated with Plaster of Paris were included. This enabled the US Project Manager to ensure that the techniques were effective against munitions stabilised against leaking.

2.5.2 The mustard munition destruction programme consisted of :

- Destruction of one free from chemical test piece to exercise changes in SOPs.
- Destruction of three 4.2" Mortars nominally containing mustard.
- Destruction of one 4.5" shell nominally containing mustard.

2.5.3 The second part of the trials process was the resumption of phosgene operations with the destruction of a Livens projectile nominally assessed as containing volatile agent and tin. The destruction of this munition was dependent upon two factors: identification of its contents by drilling, sampling and analysis followed by re-sealing the munition; and provision of a scrubber system to remove the brown smoke reported during the destruction of previous munitions containing phosgene and tin.

2.5.4 The phosgene munition destruction programme consisted of :

- Destruction of one 4" Stokes mortar nominally containing phosgene and tin.
- Destruction of two simulated Livens test pieces containing phosgene (but no tin).

2.5.5 The third part of the trials process involved the manufacture and fill of a test piece. This contained the nerve agent sarin. The US Project Manager had a requirement to test the techniques and prototype against a nominal munition containing sarin (GB). This was in direct response to urgent operational requirements as GB containing bomblets were recently been uncovered at the Rocky Mountain Arsenal in Colorado and at the time the US capability to deal with this type of problem was less than adequate.

2.5.6 DSTL provided facilities and expertise in five main areas as listed below:

- Manpower: including a toxic-trained team of 9 experienced field operations staff to supervise and operate the equipment and the undressing station, a trials conducting officer, and project and technical management.
- Analytical: provision of standards to calibrate detection equipment and analysis of samples using appropriate methods.
- Consumables: including decontamination materials and containers as required, (including specified quantities of monoethanolamine and sodium hydroxide). This includes the provision of personal protective equipment.
- Facilities: hire or purchase of a suitable generator and portacabins.
- Disposal costs: covering the incineration of toxic waste streams and the disposal of waste rinse water and solid scrap.
- Range fees: hire costs for the range area which includes concomitant range services such as area control with hazard prediction for toxic clearances, security patrols, and medical and emergency cover, as well as mandated recovery costs on capital assets to cover nominal interest on asset value, upkeep and depreciation.

2.5.7 A personal decontamination station was manned by a fully trained undressing team at all times when toxic work was being carried out.

2.6 Clean-up and Waste Disposal.

2.6.1 Dstl staff provided full support to clean up operations during the munition disposal programme. The clean up procedure to ensure that the post-trial cleanliness of the equipment is such that it can be shipped back to the US is dealt with under the main trial contract, ERO contract N68171-99-C-9026 and the first follow on contract, ERO contract N68171-00-C-9021. This current work programme included the additional costs incurred related to cleaning the vessel and trials site after use of sarin.

2.6.2 All equipment was sucessfully cleaned and returned to the US to the satisfaction of the US PM.

2.6.3 Liquid waste was stored in temporary sealed, plastic waste containers until treatment and incineration. Solid waste was stored in plastic lined bins. Low bulk solids (e.g. safety clothing or small pieces of contaminated equipment) and small volumes of contaminated

liquid (e.g. residues of samples taken for analysis) were incinerated directly in the Rotary Kiln at the CBS Porton Down incinerator. The large or bulky items of metal scrap were unsuitable for loading into the Kiln, and required disposal in the more costly fixed hearth furnace.

2.6.4 The liquid waste was dealt with in one of two ways. The monoethananolamine decontaminant solutions were disposed of via the normal solvent feed streams for the incinerator plant, involving transfer from the temporary plastic waste containers into a bulk tank before direct injection into the afterburner. It was necessary to provide analytical data on residual CW agent content for all batches of decontaminant solutions before delivery to the incineration system.

2.6.5 Rinse water, provided it was below the set limit for any CW agent, was transferred directly to the incineration facility's effluent holding tank along with the sodium hydroxide decontaminant solution where was fed into the process (heavily diluted) for cooling purposes. Any substances likely to remain in this water will be forced out of solution on vaporisation, and would thence collect in the filter cake. Analytical information on each batch sent to the facility was necessary to provide assurance of the absence of CW agent.

2.7 Technology Transfer.

2.7.1 Personnel were provided ensure effective technology transfer and to provide programme support in the US. This phase in the contract covered the cost of a technical consultancy team (two persons) for 5 weeks to the US and two programme support teams (two persons each) to the US for a period of 2 weeks each. These personnel were under the direction of the US project manager whilst in the US.

2.8 Analysis

2.8.1 Dstl provided standards for phosgene, mustard and sarin at the concentrations and frequency required, under discussion with the US monitoring team. These standards were used by the US team to calibrate their continuous monitoring (Minicams) and the environmental monitoring (DAAMS/GCMS) equipment.

2.8.2 Dstl also provided analysis of post-detonation neat agent samples provided by FTIR or GCMS. Methodologies supplied by the US team were used for the analysis of post decontamination mustard samples. Selected waste samples were also analysed using

standard environmental monitoring methods. Air monitoring was performed by Dstl staff with CAMs and Draeger tubes to ensure the safety of personnel whilst working on the trial.

2.9 Liaison with Regulatory Authorities

2.9.1 Dstl co-ordinated and was responsible for all interfaces with the appropriate authorities relating to the movements and operations for the trials in the UK. This included arranging documentation and declarations relating the Chemical Weapons Convention, as well as authorisations necessary from UK national and regional authorities. Dstl was responsible for liaison with the UK Customs to arrange import and export licenses and the US team was responsible for equivalent discussions with US Customs.

2.10 Safe Operations and Safety Documentation

2.10.1 DSTL provided comments as required on the US provided SOPs and risk assessments used to guide the safety management of the trials work. Dstl staff are used to working in an environment controlled by the strict application of such procedures, and have considerable expertise in the formulation of SOPs and risk assessments to provide the greatest possible level of safety. In addition, the Dstl trials team gained considerable experience operating with previous EDS prototypes during earlier work at Porton Down.

2.10.2 All members of the Dstl team work routinely in the laboratory and in the field with toxic and explosive materials. Due to the necessity of working with these materials, safety is taken very seriously at Dstl. The Chief Executive of Dstl issues annually a personally signed safety statement in which he stresses the paramount importance of safety.

2.10.3 Civilian legislative requirements laid down in the 1974 Health and Safety at Work Act and the more recent European Community legislation were, as always, strictly adhered to and where appropriate higher standards were used. Dstl staff do not work to military regulations unless these are more stringent than the civilian requirements. The current limits in force for exposure to the agents of interest are 0.5 mg min^{-1} m^{-3} for mustard (a site specified limit) and 0.25 mg min^{-1} m^{-3} for phosgene (the UK industry standard Short Term Exposure (STEL), which is based on a 15 minute reference period.

2.10.4 Dstl Porton Down provided emergency response cover teams for the trials, including both spill response and medical emergency. SOPs were drafted to ensure that the effect on personnel and the environment of any spill or release is minimal; and the worst credible incident was used when setting downwind hazard exclusion areas for toxic work. The

quantities of agent and other hazardous material stored and used at any one time was minimised. First aid equipment was provided at the trial site throughout the operation and at least one of the operators was qualified to administer first aid to chemical agent casualties. In addition, Dstl Porton Down has a fully equipped site hospital which was permanently manned by trained and experienced medical staff throughout toxic working periods.

2.10.5 Dstl Porton Down has the capability to perform trials activities with personnel protected by a SCBA and gas-tight suit ensemble, and this is available on-site if necessary. The aim, however, is to use careful trials design so as to eliminate the need for personnel to wear SCBA. It was considered that, for the trials reported, full Individual Protective Equipment (IPE) consisting of respirator and NBC suit with boots and gloves (together with impermeable oversuit if necessary) was be fully capable of adequately protecting personnel against the expected worst case challenge.

3. Conclusions

3.1 All test pieces were successfully destroyed and the US team obtained all the data required to the satisfaction of the US PM. In addition, SOP modifications were verified and fully validated to ensure fully safe operations of the EDS prototype equipment.

3.2 The EDS prototype, as originally configured, had proved unable to meet the chemical challenge of taking neat agent samples and oscillating under the weight of a full munition/test piece loading. The system modifications described in earlier reports were designed to correct this. These were fully validated by the trials in order to ensure that the EDS prototype is now robust against both these challenges

3.3 The mustard and phosgene test pieces and munitions described in this report have increased the confidence that the EDS system can now successfully destroy munitions containing these agents. The destruction of a test piece containing sarin has provided proof of principle for the prototype to be safely used against sarin-containing munitions.

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Annex A – Financial Information

The table below gives costs for the work covered by this report. This relates to two applied research proposals (Applied Research Proposal for the Explosive Destruction of Chemical Munitions, submitted 6th March 2001, and Addition to the Applied Research Proposal for the Explosive Destruction of Chemical Munitions, submitted 2nd July 2001) covered by ERO Contract No. N68171-01-C-9014, which makes up the total invoiced value of USD $736,357.40.

A1 – Information from Applied Research Proposal for the Explosive Destruction of Chemical Munitions.

A) MANPOWER CHARGES	UNITS	QUANTITY	TOTAL UNITS	PRICE PER UNIT (USD)	PRICE (USD)
Engineer	**Hours**		**153**	**71.50**	**10,939.50**
Maintenance and Modification of Equipment		48			
Construction of vessel for GB		10			
Munition Disposal Programme		95			
Full Toxic Team	**Hours**		**540**	**412.70**	**222,858.00**
Training and Walkthrough Testing in New SOPs		45			
Munition Disposal Programme		495			
Trials Conducting Officer	**Hours**		**980**	**96.30**	**94,374.00**
Training and Walkthrough Testing in New SOPs		45			
Munition Disposal Programme		495			
Production of Trials Programme/Safety Briefings		120			
Consultancy and technology transfer in US		320			
Project Manager	**Hours**		**700**	**96.30**	**67,410.00**

Maintenance and Modification		20			
Training and Walkthrough Testing in New SOPs		40			
Munition Disposal Programme		460			
Project Management Support (incl. Regulatory procedures, financial control and report writing)		180			
Technical Manager	**Hours**		**115**	**129.50**	**14,892.50**
Maintenance and Modification		15			
Munition Disposal Programme		100			
Lead Analyst	**Hours**		**140**	**96.30**	**13,482.00**
Munitions Disposal Programme		140			
Analyst	**Hours**		**256**	**71.50**	**18,304.00**
Munitions Disposal Programme		250			
Fill of GB container		6			
Team Leader	**Hours**		**625**	**53.10**	**33,187.50**
Maintenance and Modification		45			
Consultancy and technology transfer in US		320			
Programme support in US (2 people @ 2 weeks)		260			
Team Member	**Hours**		**305**	**40.00**	**12,200.00**
Maintenance and Modification		45			
Programme support in US (2 people @ 2 weeks)		260			
PINS Leader	**Hours**		**90**	**96.30**	**8,667.00**
PINS Re-assessment		90			

PINS Assistant	**Hours**		**110**	**53.10**	**5,841.00**
PINS Re-assessment		110			
Additional Medical Services	**Day**		**2**	**2,400.00**	**4,800.00**
Additional medical cover during GB disposal		1			
Day rate for provision of Colin Esterase Jabs for all personnel		1			
Administrative Assistant	**Hours**		**112**	**39.6**	**4,435.20**
Administration Support		112			
MANPOWER TOTAL					**511,390.70**
B) FACILITY CHARGES	**UNITS**	**QUANTITY**	**TOTAL UNITS**	**PRICE PER UNIT (USD)**	**PRICE (USD)**
Range Facility	**Month**		**3**	**23,486.20**	**70,458.60**
Use of Range Facility		3			
Use of Single Small Scale Facility	**Day**		**1**	**4,000.00**	**4,000.00**
Use of SSSF for supply of sarin and container fill		1			
Waste Disposal	**Drum**		**2**	**1,653.90**	**3,307.80**
Disposal of Decontaminant Solution (Monoethanolamine)		2			
Disposal – NaOH	**Drum**		**2**	**30.10**	**60.20**
Disposal of Decontaminant Solution (Sodium Hydroxide)		2			
Disposal – Rinse Water	**Drum**		**20**	**30.10**	**602.00**
Disposal of Rinse Water		20			

Disposal – Munition Waste	**Drum**		**5**	**1,503.50**	**7,517.50**
Disposal of Munition Waste		5			
Disposal – Other Waste	**Kg**		**100**	**12.80**	**1,280.00**
Disposal of Solid Waste (NBC Suits, Splash suits, Gloves etc.)		100			
FACILITIES TOTAL					**87,226.10**
C) MATERIALS CHARGES	**UNITS**	**QUANTITY**	**TOTAL UNITS**	**PRICE PER UNIT (USD)**	**PRICE (USD)**
Hire of Generator	**Week**		**13**	**864.00**	**11,232.00**
Hire of Generator		13			
Fuel for Generator	**Litre**		**2500**	**0.37**	**925.00**
Fuel for Generator		2500			
Portacabin Units	**Week**		**23**	**120.30**	**2,766.90**
Portacabin units		23			
Sodium Hydroxide	**Drum**		**2**	**57.50**	**115.00**
Sodium Hydroxide		2			
Monoethanolamine	**Drum**		**2**	**209.60**	**419.20**
Monoethanolamine		2			
Waste Disposal Drums	**Drum**		**20**	**36.10**	**722.00**
Waste Disposal Drums		20			
Air Cylinder	**Cylinder**		**2**	**48.40**	**96.80**

Air Cylinder		2			
Nitrogen Cylinder	**Cylinder**		**6**	**164.10**	**984.60**
Nitrogen Cylinder		6			
Custom Charges	**Each**		**1**	**1,500.00**	**1500.00**
Miscellaneous Customs Charges for Import/Export of materials		1			
Engineering Charges	**Each**		**1**	**2,500.00**	**2500.00**
Estimate for Engineering Spares and Service Charges		1			
External Analysis	**Each**		**16**	**751.80**	**12,028.80**
External Analysis Costs		16			
Flights	**Each**		**6**	**1,353.20**	**8,113.20**
Flexible flights for 6 people to US		6			
Hire Cars	**Week**		**9**	**375.90**	**3,383.10**
Hire car for 3 visits to US (2 x 2 weeks and 1 x 5 weeks)		9			
Subsistence	**Day**		**138**	**192.00**	**26,496.00**
Accommodation and Food for US visits (per person per day)		138			
	Day		**138**	**16**	**2,208.00**
Miscellaneous Expenses for 3 visits to US (per person per day)		138			
MATERIALS TOTAL					**73,490.6**
TOTAL COSTS FOR THIS SECTION					**672,107.40**

A2 – Information from Addition to the Applied Research Proposal for the Explosive Destruction of Chemical Munitions.

A) MANPOWER CHARGES	UNITS	QUANTITY	TOTAL UNITS	PRICE PER UNIT (USD)	PRICE (USD)
Level 3 (Demil Off-site team member)	Hours	1477	1477	42.05	62,107.85
MANPOWER TOTAL					**62,107.85**
B) FACILITY CHARGES	**UNITS**	**QUANTITY**	**TOTAL UNITS**	**PRICE PER UNIT (USD)**	**PRICE (USD)**
None					0
FACILITIES TOTAL					**0**
C) MATERIALS CHARGES	**UNITS**	**QUANTITY**	**TOTAL UNITS**	**PRICE PER UNIT (USD)**	**PRICE (USD)**
Flexible flights (return) to US	Each	3	3	714.05	2,142.15
MATERIALS TOTAL					**2,142.15**
TOTAL COSTS FOR THIS SECTION					**64,250.00**